analyze_aoslo_data_large

August 28, 2015

Script to load and visualize high frequency AOSLO data Further, I look into low-pass filtering the data to smooth out experimental artifacts

In [1]:
```
import numpy as np
import os
from scipy.io import loadmat
from scipy.signal import butter, lfilter, freqz
from scipy.interpolate import interp1d
from pykalman import KalmanFilter
import matplotlib.pyplot as plt
%matplotlib inline
```

1 Load Data

In [2]:
```
data_dir = 'data_high_freq/'
fn_s = [fn for fn in os.listdir(data_dir) if fn.endswith('.mat')]
fn_s
```

Out[2]:
```
['20094L_020_cw_nostim_bandfilt_1920_hz_8199.mat',
 '20094L_022_cw_nostim_bandfilt_1920_hz_304.mat']
```

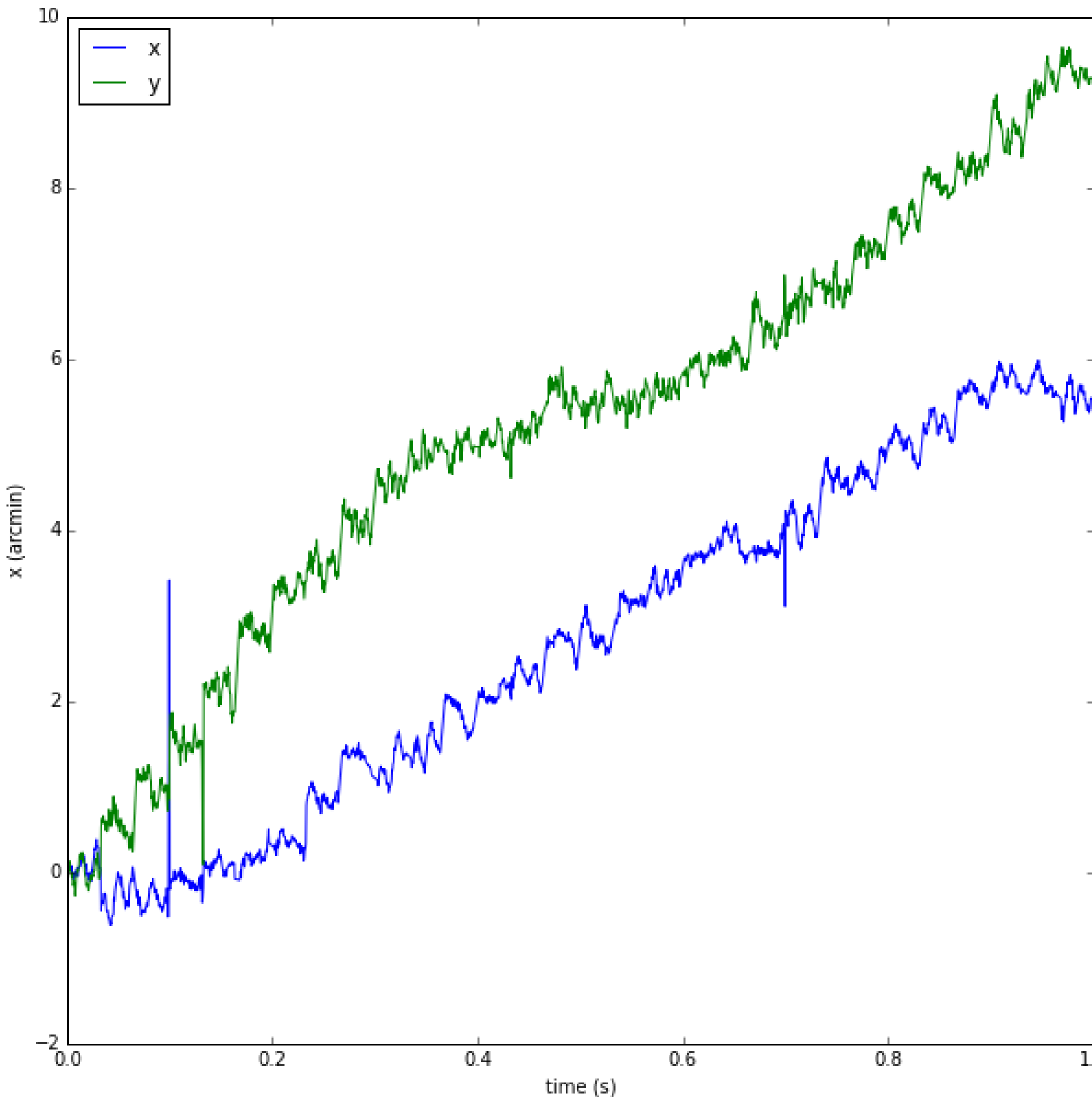
In [26]:
```
data = loadmat(os.path.join(data_dir, fn_s[1]))
```

In [27]:
```
scale = 1. / 392. * 60. # Conversion from pixels to arcmins
```

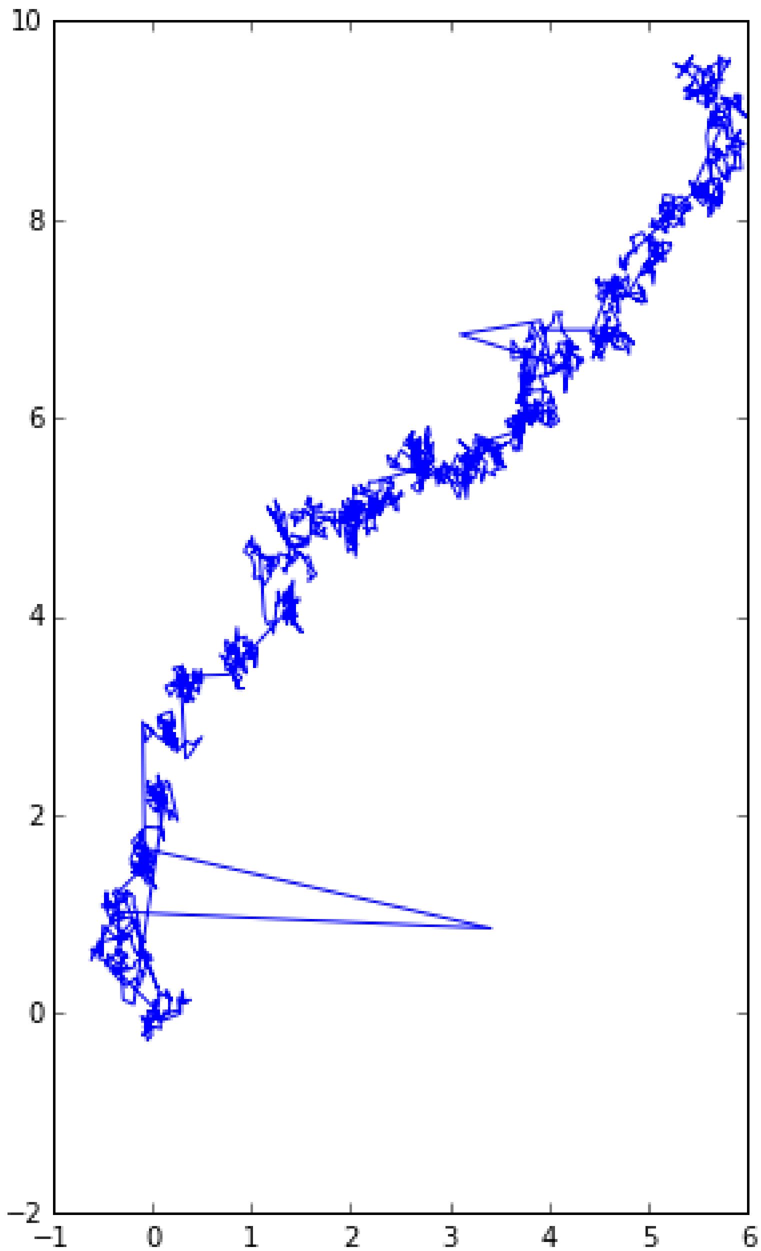
In [28]:
```
t = data['timeaxis_secs'][:, 0]
t = t - t[0]
xy = data['frameshifts_strips_spline'] * scale
x = data['frameshifts_strips_spline'][:, 0] * scale
y = data['frameshifts_strips_spline'][:, 1] * scale
x = x - x[0]
y = y - y[0]
```

In [29]:
```
plt.figure(figsize = (10, 10))
plt.plot(t, x, label = 'x')
plt.plot(t, y, label = 'y')
plt.xlabel('time (s)')
plt.ylabel('x (arcmin)')
plt.legend(loc = 0)
```

Out[29]:
```
<matplotlib.legend.Legend at 0x10e144a50>
```




```
In [30]: plt.figure(figsize=(8,8))
         plt.plot(x, y)
         plt.axes().set_aspect('equal')
```



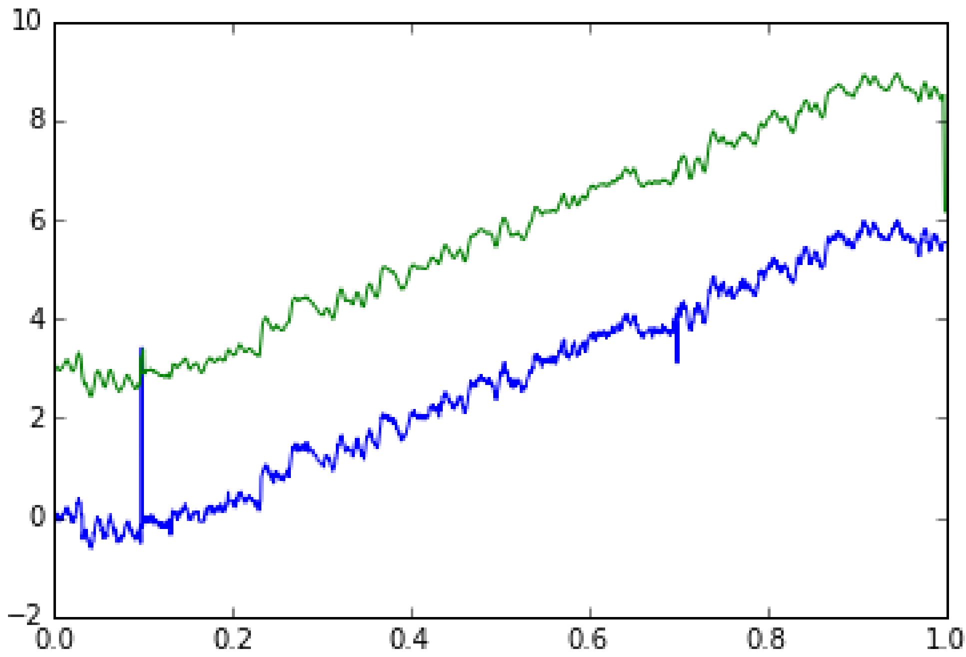
Notice that there are jumps in the data, these should be smoothed out using a filter.

```
In [31]: def moving_average(x, y, a = 7):
             """
             Moving average to smooth out 'jumps'
             a = 7 suggested by Roorda group
             """
             f = np.ones((a,))/ (1.0 * a)
             xf = np.convolve(f, x, mode = 'same')
             yf = np.convolve(f, y, mode = 'same')
             return xf, yf
```

In [32]:
```
xf, yf = moving_average(x, y)
xyf = np.zeros_like(xy)
xyf[:, 0] = xf
xyf[:, 1] = yf
```

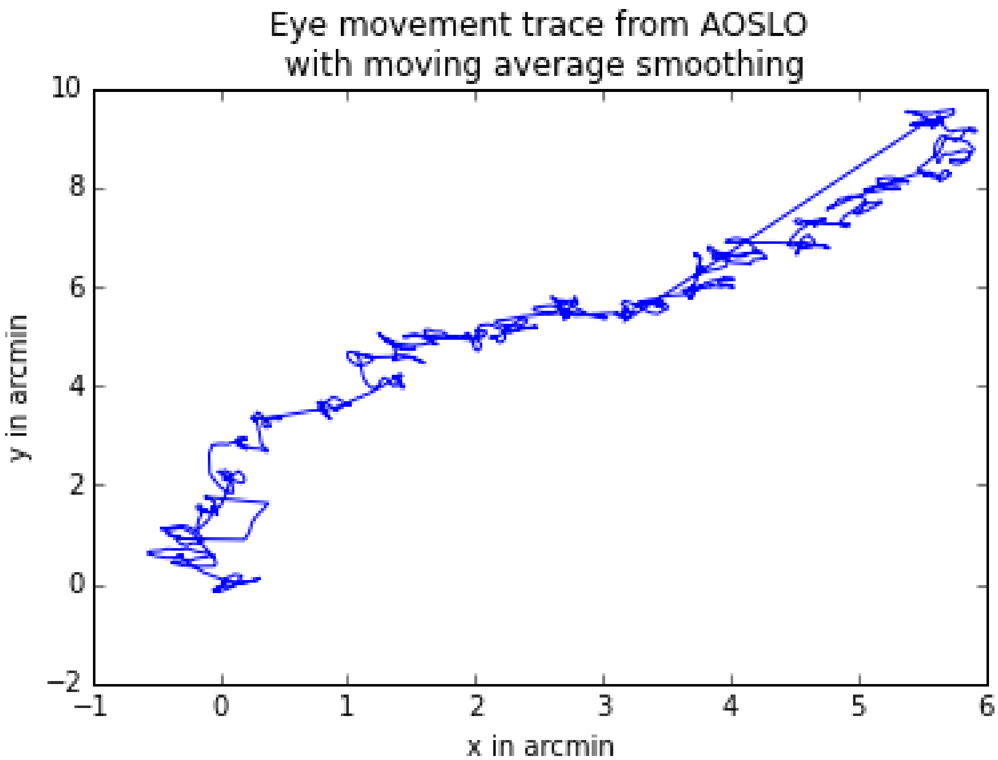
In [33]:
```
plt.plot(t, x, t, xf + 3)
```

Out[33]:
```
[<matplotlib.lines.Line2D at 0x11591df50>,
 <matplotlib.lines.Line2D at 0x11592c210>]
```



In [34]:
```
plt.plot(xf, yf)
plt.xlabel('x in arcmin')
plt.ylabel('y in arcmin')
plt.title('Eye movement trace from AOSLO\n with moving average smoothing')
```

Out[34]:
```
<matplotlib.text.Text at 0x118f94a10>
```



Note that even though the data is at 3840 Hz, the system locks on to something and then jumps. Kavitha thinks that it is related to the tumbling E in the middle that she attempts to filter out (i.e. the jumps happen at the frequency of when the tumbling E changes).

2 Kalman Smoothing

```
In [35]: e1 = np.array([[1, 0, 0, 0],
                        [0, 0, 0, 0],
                        [0, 0, 1, 0],
                        [0, 0, 0, 0]])

         e2 = np.array([[0, 0, 0, 0],
                        [0, 1, 0, 0],
                        [0, 0, 0, 0],
                        [0, 0, 0, 1]])
```

```
In [36]: dt = t[1] - t[0]
```

0.2 s - delta v = 30 arcmin/s acceleration -> 150 arcmin/s^2 4000 samples / s 150 / 4000 = 0.04 arcmin/s/sample

```
In [37]: 150./4000

Out[37]: 0.0375
```

```
In [38]: sigma_p = 30. # Initial velocity standard deviation arcmin/s
         sigma_t = 0.04 # Hidden state transition noise
         sigma_o = 0.01 # Observation noise
```

In [39]:
```
kf = KalmanFilter(transition_matrices = [[1, dt, 0, 0],
                                         [0, 1, 0, 0],
                                         [0, 0, 1, dt],
                                         [0, 0, 0, 1]],
                  transition_covariance = sigma_t * e2,
                  observation_matrices = [[1, 0, 0, 0],
                                          [0, 0, 1, 0]],
                  observation_covariance = sigma_o * np.eye(2),
                  initial_state_mean = np.zeros(4),
                  initial_state_covariance = sigma_p * e2
                  )

measurements = xyf
#kf = kf.smooth(measurements)
#kf = kf.em(measurements, n_iter=5)
#(filtered_state_means, filtered_state_covariances) = kf.filter(measurements)
(smoothed_state_means, smoothed_state_covariances) = kf.smooth(measurements)
```

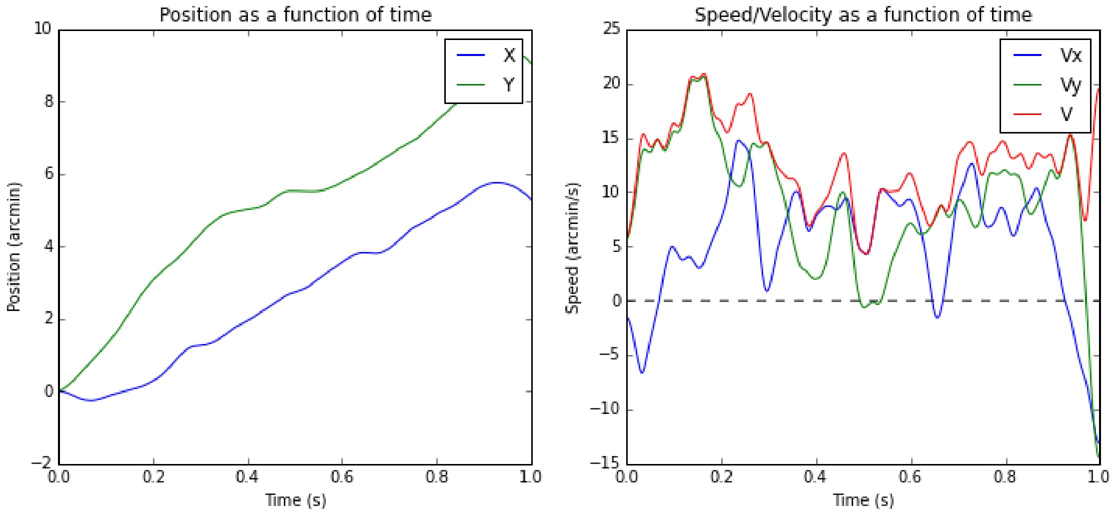
In [40]:
```
np.round(smoothed_state_covariances[-1], decimals = 2)
```

Out[40]:
```
array([[ 0.  ,  0.02,  0.  ,  0.  ],
       [ 0.02,  1.75,  0.  ,  0.  ],
       [ 0.  ,  0.  ,  0.  ,  0.02],
       [ 0.  ,  0.  ,  0.02,  1.75]])
```

In [41]:
```
Xh = smoothed_state_means[:, (0,2)]
Vh = smoothed_state_means[:, (1,3)]
```

In [42]:
```
plt.figure(figsize = (12, 5))
plt.subplot(1, 2, 1)
plt.plot(t, Xh[:, 0], label = 'X')
plt.plot(t, Xh[:, 1], label = 'Y')
plt.legend()
plt.xlabel('Time (s)')
plt.ylabel('Position (arcmin)')
plt.title('Position as a function of time')

plt.subplot(1, 2, 2)
plt.plot(t, Vh[:, 0], label = 'Vx')
plt.plot(t, Vh[:, 1], label = 'Vy')
plt.plot(t, np.sqrt(Vh[:, 0] ** 2 + Vh[: , 1] ** 2), label = 'V')
plt.plot(t, np.zeros_like(t), 'k--')

plt.title('Speed/Velocity as a function of time')
plt.xlabel('Time (s)')
plt.ylabel('Speed (arcmin/s)')
plt.legend()
```

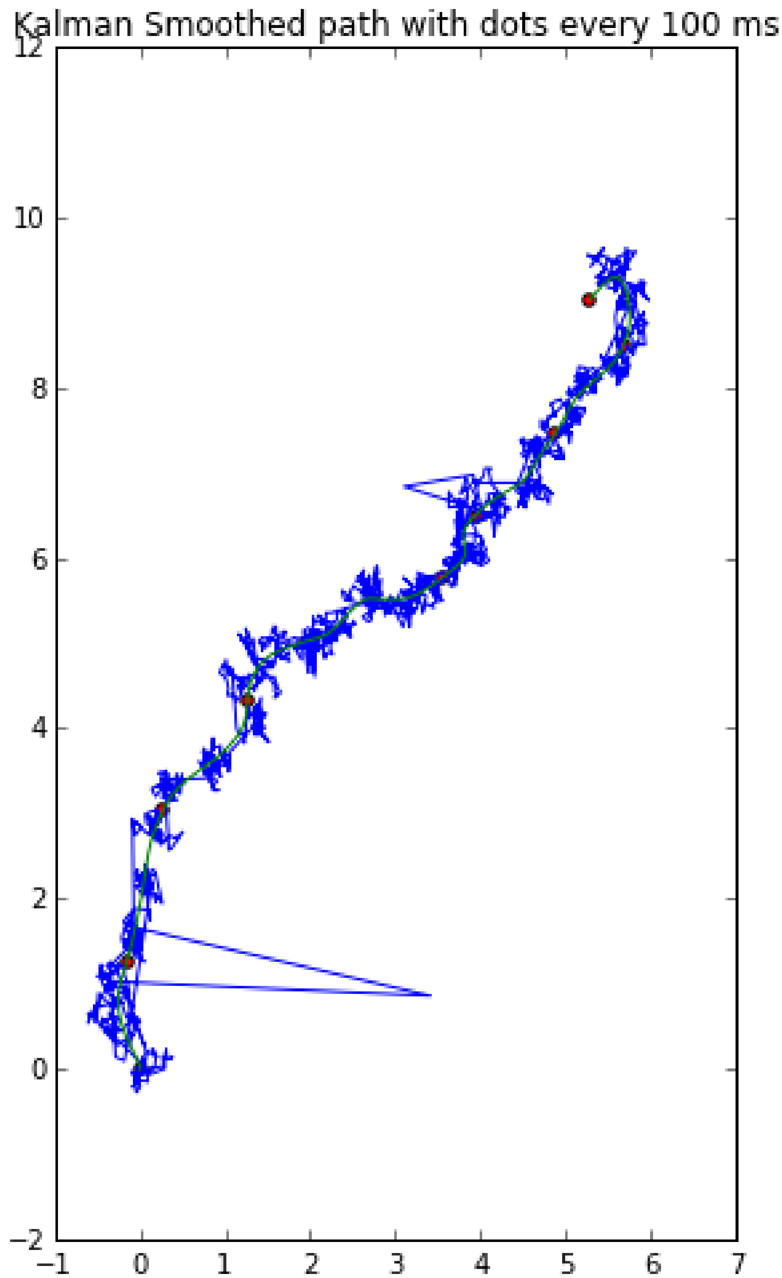
Out[42]:
```
<matplotlib.legend.Legend at 0x119137890>
```




```
In [43]: colors = np.convolve(np.array([1,-1]), np.floor(t * 1.001 / 0.1 - 0.0001), mode = 'same')
         idx = np.where(colors == 1)[0]
```

```
In [44]: plt.figure(figsize = (8, 8))
         plt.plot(x, y)

         plt.plot(Xh[:, 0], Xh[:, 1])
         plt.scatter(Xh[idx, 0], Xh[idx, 1], c = 'r')
         plt.axes().set_aspect('equal')
         plt.title('Kalman Smoothed path with dots every 100 ms')
```

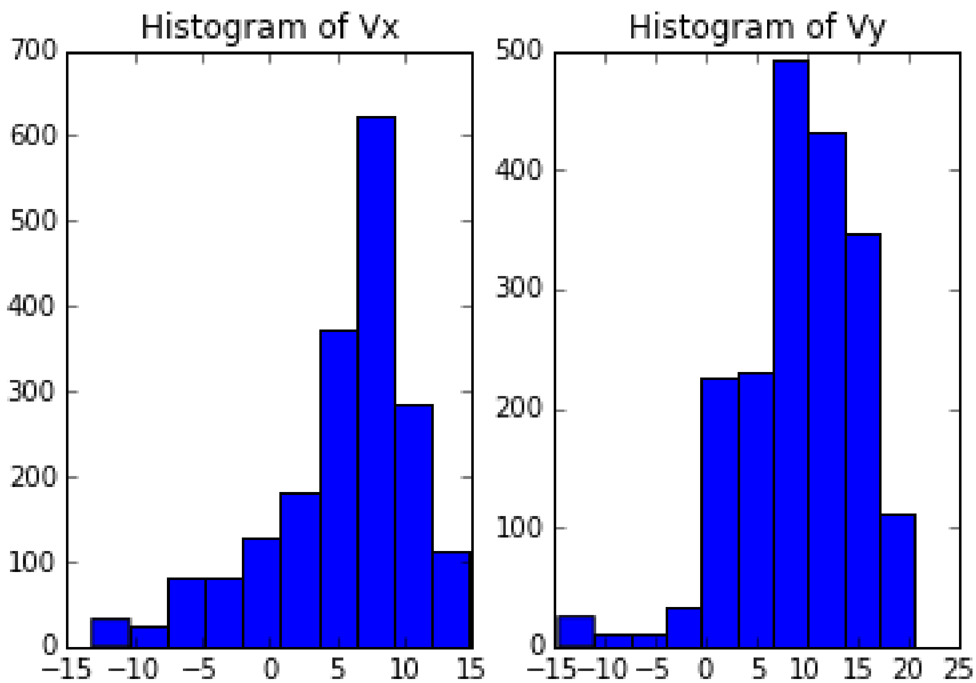
```
Out[44]: <matplotlib.text.Text at 0x11cd1ee90>
```



3 Model Validation: Histograms of Velocity

```
In [45]: plt.subplot(1, 2, 1)
         plt.title('Histogram of Vx')
         plt.hist(Vh[:, 0])
         plt.subplot(1, 2, 2)
         plt.title('Histogram of Vy')
         plt.hist(Vh[:, 1])
```

```
Out[45]: (array([  25.,   11.,   10.,   33.,  226.,  231.,  492.,  433.,  347.,  112.]),
          array([-14.45307726, -10.94747138,  -7.4418655 ,  -3.93625962,
                  -0.43065375,   3.07495213,   6.58055801,  10.08616389,
                  13.59176977,  17.09737564,  20.60298152]),
          <a list of 10 Patch objects>)
```

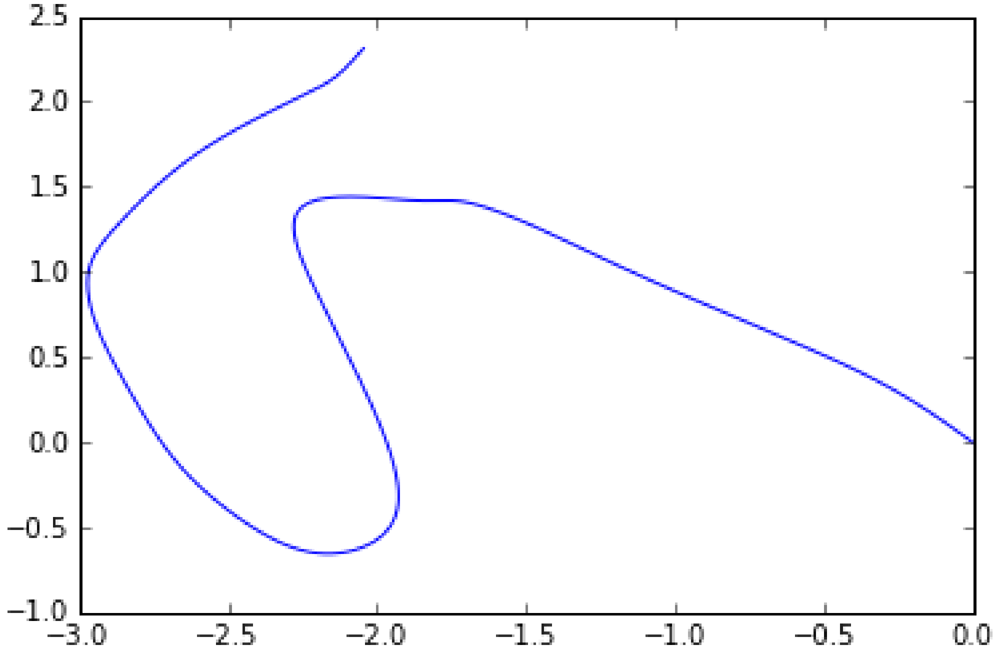



```
In [ ]:
```

4 Resampling

In order to do simulations, we will resample the smoothed data at 1000 Hz to go with the other simulations

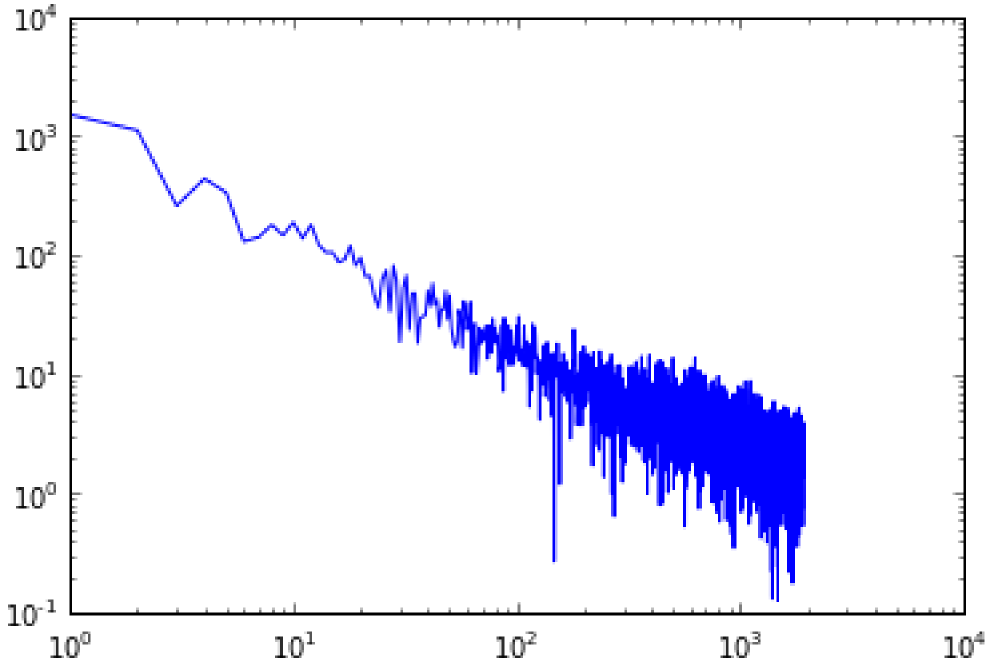
```
In [23]: resample_dt = 0.001 # seconds / sample
         tp = np.arange(0, 1, resample_dt)

In [24]: fx = interp1d(t, Xh[:, 0])
         fy = interp1d(t, Xh[:, 1])
         x_i = fx(tp)
         y_i = fy(tp)

In [25]: plt.plot(x_i, y_i)

Out[25]: [<matplotlib.lines.Line2D at 0x114783d50>]
```



5 Power Spectrum

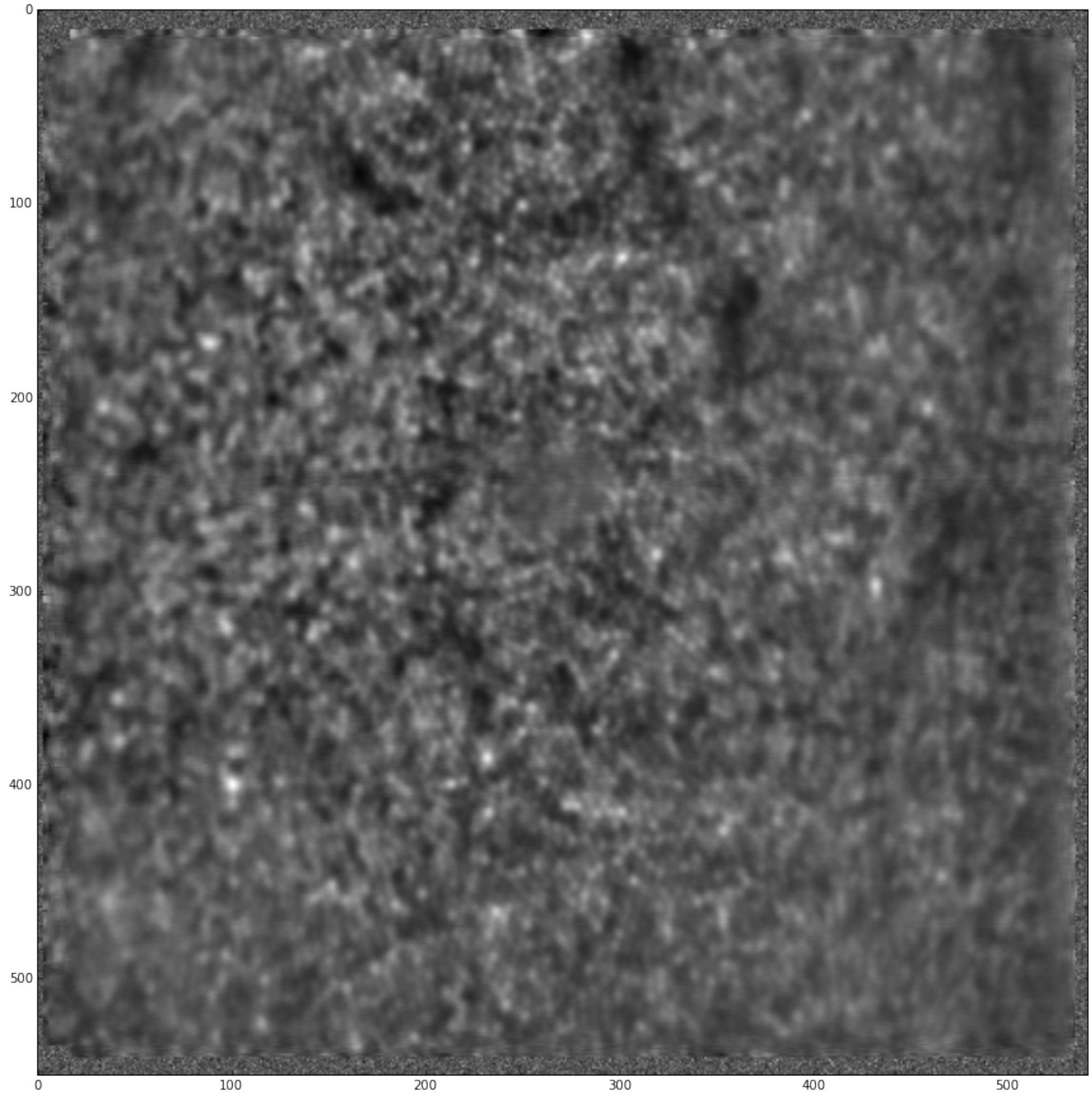
In [26]:
```
ps = np.fft.fftshift(np.abs(np.fft.fft(x)))
freqs = np.fft.fftshift(np.fft.fftfreq(x.size, 1/ 3840.))
```

In [27]:
```
plt.plot(freqs, ps)
plt.yscale('log')
plt.xscale('log')
```



6 Reference Image

```
In [28]: plt.figure(figsize=(15, 15))
         plt.imshow(data['referenceimage'], cmap = plt.cm.gray)

Out[28]: <matplotlib.image.AxesImage at 0x115248090>
```



7 Lowpass filtering

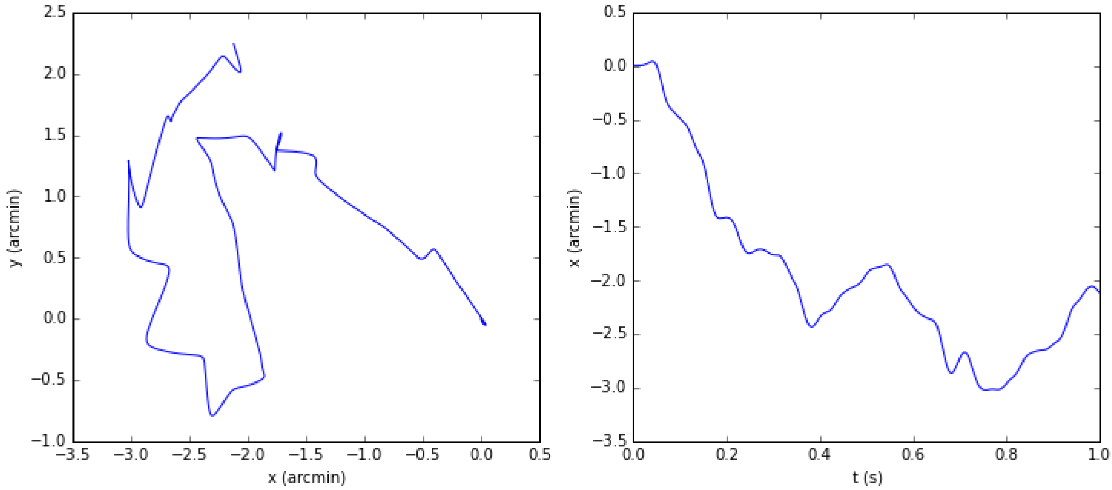
As the movement should be quantized as it looks like before, we do a more aggressive filtering

In [29]:
```
def butter_lowpass(cutoff, fs, order=5):
    nyq = 0.5 * fs
    normal_cutoff = cutoff / nyq
    b, a = butter(order, normal_cutoff, btype='low', analog=False)
    return b, a

def butter_lowpass_filter(data, cutoff, fs, order=5):
    b, a = butter_lowpass(cutoff, fs, order=order)
    y = lfilter(b, a, data)
    return y
```

```
In [30]: cutoff = 20. #Hz
         xb = butter_lowpass_filter(x, cutoff, 3840.)
         yb = butter_lowpass_filter(y, cutoff, 3840.)
```

```
In [31]: plt.figure(figsize = (12, 5))
         plt.subplot(1, 2, 1)
         plt.plot(xb, yb, '-')
         plt.xlabel('x (arcmin)')
         plt.ylabel('y (arcmin)')
         plt.subplot(1, 2, 2)
         plt.plot(t, xb)
         plt.xlabel('t (s)')
         plt.ylabel('x (arcmin)')
```

```
Out[31]: <matplotlib.text.Text at 0x117d2b190>
```



Notice that this doesn't look very good to just low pass the eye movements.

```
In [ ]:
```